EFFECT OF FERTILIZER N ON SPRING WHEAT PRODUCTION ON A ZERO TILLAGE SNOW TRAP SYSTEM IN THE BROWN SOIL ZONE

F. Selles, C.A. Campbell, R.P. Zentner, and F.B. Dyck
Research Station,
Research Branch, Agriculture Canada,
SWIFT CURRENT, Saskatchewan. S9H 3X2

INTRODUCTION

Farmers of southwestern Saskatchewan are affected, among other problems, by low farm returns and high incidence of soil erosion and degradation. The main source of this problem lies in the fact that in this area the potential evaporation is larger than the annual precipitation. Further, not only is there usually a water shortage, but the distribution of growing season precipitation often is a major deterrent to achieving consistently good yields.

It is this scenario which leads to the high incidence of summerfallow with the cropping schemes practiced in the Brown soil zone, even though from 1974 the incidence of summerfallow in the Dark Brown and Black soil zones has declined substantially (Fig. 1).

This high incidence of summerfallow is detrimental to the farming operation because firstly, one-half of the land sits idle for one year, thus providing no income; and secondly, land in bare fallow is easily eroded and degraded, thus lowering its productivity. About one-third of the annual precipitation comes as snow, and it has been estimated that 30 mm of available water could be obtained from snow, providing it is properly managed (de Jong and Cameron 1980).

The experience acquired indicates that tall stubble is more effective in trapping snow than short stubble (Janzen et al. 1960; Willis et al. 1969; Steppuhn 1981). Further, in the Brown soil zones of Saskatchewan 20-30% more snow was trapped in stubble cut at alternate heights than in stubble cut at a low uniform height (Nicholaichuk and Norum 1975), and over a 7-year period an average 13 mm extra soil water was obtained from this additional snow trapped.

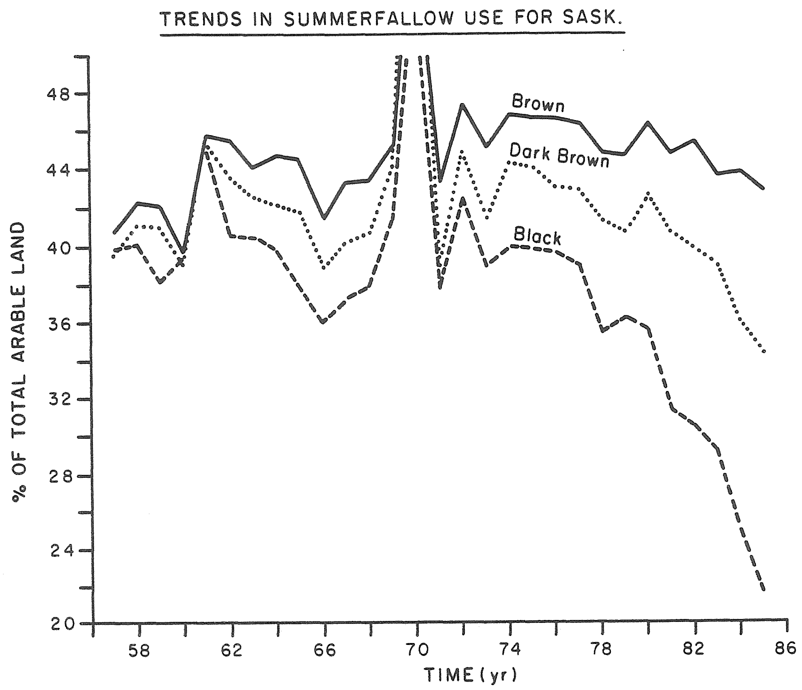

Fig. 1. Proportion of summerfallowed land in Saskatchewan

Before the water can be obtained from the extra trapped snow, however, it must infiltrate into the soil. Poor infiltration of snowmelt occurs when the soil becomes frozen at the surface in fall or winter (de Jong and Steppuhn 1973). Early studies have indicated that on tilled stubble an average 37% of the fall and winter precipitation could be conserved in the Brown soil zone (Staple et al. 1960), whereas in soils under zero till, infiltration is superior to that on conventionally tilled land (Cannell et al. 1979; Wells 1984).

The response of cereals to fertilizer is intimately linked to the amount of water available for crop growth (de Jong and Rennie 1967; Campbell et al. 1977). Further, the placement of the fertilizer and its time of application influence the crop response when moisture levels are adequate (Randall 1984, Penny 1985). In dryland agriculture, then, the amount of available water becomes the most critical factor in determining the level of crop yields that can be obtained.

In 1980 an experiment was designed to assess the response of spring wheat (*Triticum aestivum* L.) to snow and fertilizer management and on the amount of winter precipitation conserved when growing annually on zero-tilled land. (Fig. 2).

Fig. 2. General view of snow trapped by cereal trap strips

MATERIALS AND METHODS

Main Treatments

Main treatments were (a) land with trap strips, a portion of stubble 40-60 cm tall by 30 cm wide every width of the swather (6 m) running in a north-south direction (perpendicular to the prevailing winds), and (b) land where the stubble was cut to one uniform height (15 cm) (i.e., standard method).

Sub Treatments

Each main treatment area was divided into three areas. Into one of these areas each year different fertility treatments were superimposed. The other two areas (filler plots) were used to burn off the residual effect of the fertilizer treatment (Fig. 3).

The fertility treatments were six combinations of N and P rates. Initially, these rates were 25/120, 50/120, 100/120, 150/120, 100/60, and 100/30 $kg.ha^{-1}$ N/$kg.ha^{-1}$ P_2O_5. During 1982-83 a 75/120 $kg.ha^{-1}$ N and P_2O_5 treatment was included instead of the 150/120 rate. Because it was found that the fertilizer P rates were too high, in 1984-85 these rates were changed to 25/60, 50/60, 75/60, 100/60, 100/45, and 100/30 $kg.ha^{-1}$ N/$kg.ha^{-1}$ P_2O_5.

Each one of these fertility treatments was further divided into four sub-sub treatments: fall band, fall broadcast, spring band, and spring broadcast of the nitrogen fertilizer (Fig. 3). Urea (46-0-0) was the source of nitrogen. All P was deep banded (12-15 cm) in the fall as treble superphosphate (0-45-0). In addition, the test plots received 25 $kg.ha^{-1}$ of S as elemental sulfur broadcast and 60 $kg.ha^{-1}$ of K_2O as potash. A minimum amount of N was added to the rest plots in order to obtain good plant growth to burn-off the residual effect of the treatments. All plots were planted to Canuck spring wheat at a rate of 67 $kg.ha^{-1}$ with a row spacing of 17.8 cm directly into standing stubble with a zero-till offset disc drill. No-till cropping was chosen because we wanted to keep stubble knock-down at a minimum.

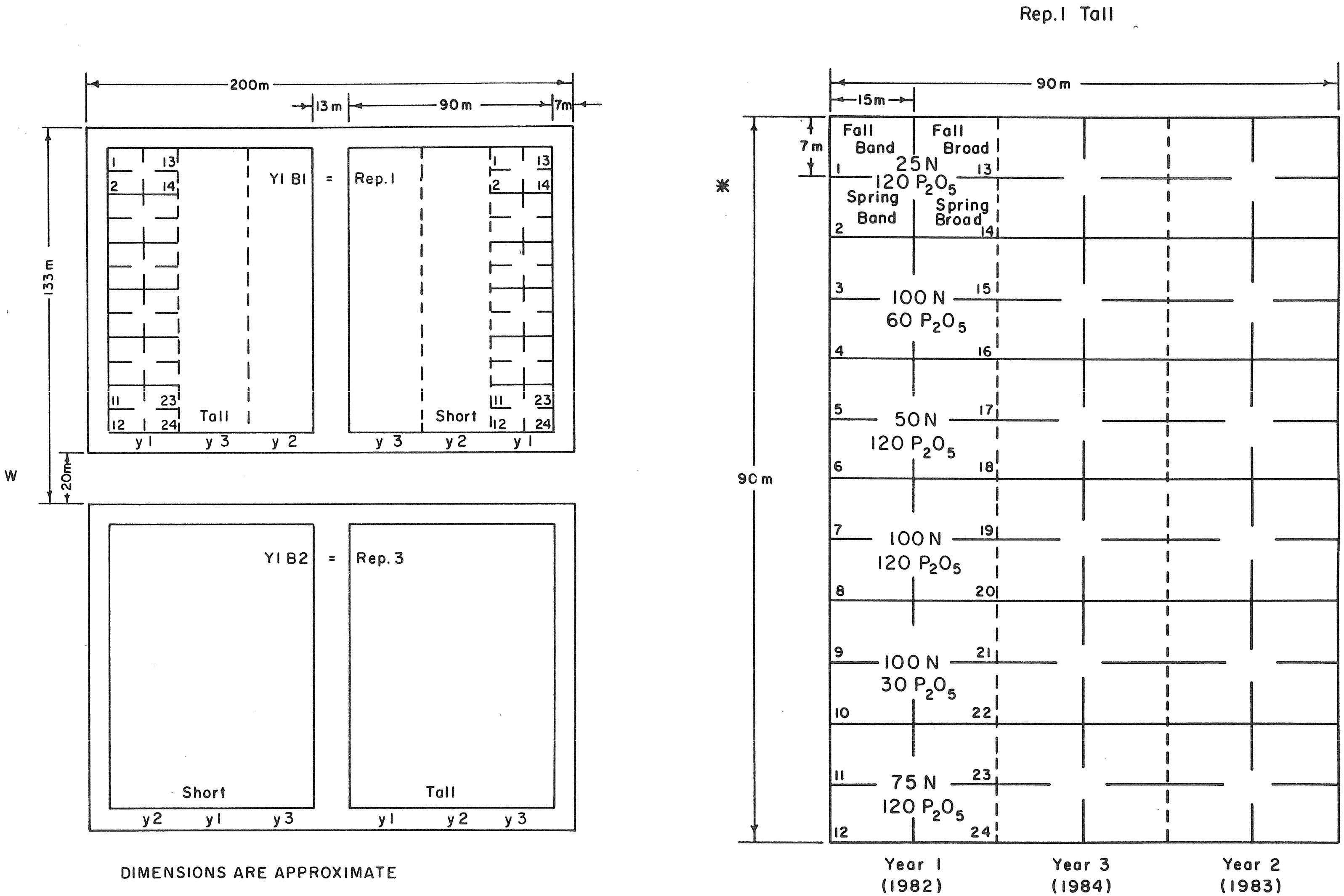

Fig. 3. Left: general plot layout in the field; Right: Detailed plot layout for fertilizer treatments

Broadleaf herbicides were used in the fall for control of winter annual weeds, and also as required prior to planting and for in-crop weed control. A summary of the herbicide applications is presented in Table 1.

To date, the test has been carried on for 5 years: one year preparing the trap strips from wheat grown on fallow and four years of test.

Table 1. Herbicide requirements (1982-1985)

Herbicide	Date	Rate (L prod ha^{-1})
1982		
2,4-D Ester 128	Oct. 17	0.53
Buctril M	June 3 & 18	1.40
2,4-D Ester 128	June 3 & 18	0.70
1983		
2,4-D Ester 500	Oct. 27	0.84
Hoegrass	June 16	3.75
Torch	June 16	1.25
1984		
2,4-D Ester 600	Oct. 13	0.69
Hoegrass Ii	June 5	3.50
1985*		
Roundup	May 11	1.20
Ag Surf	May 11	0.35
Torch	May 11	1.25
Hoegrass II	June 14	3.50
2,4-D Ester 600	Oct. 24	0.84

* There was no fall 2,4-D treatment because of the onset of an early winter.

RESULTS

Water Conserved Overwinter

The amount of water conserved in the soil during each of the four years of study has been increased substantially in the tall stubble treatment (trap strips). This advantage was 0.9, 0.5, 2.5 and 2.7 cm of extra soil moisture in 1981-82, 1982-83, 1983-84 and 1984-85, respectively.

Also interesting was the fact that the entry of snowmelt water into the soil seems to be improving with time (Fig. 4). This land had been in wheat-fallow for a long time prior to this study. We suspect that the zero-tillage has improved the surface soil tilth and that this has increased water infiltration and reduced loss of snowmelt by runoff. Further, there is evidence that, in the early stages of growth of the crop, the crop and the soil are being protected by the standing stubble from the drying winds so that the crop escapes severe drought for a much longer time than conventionally grown crops.

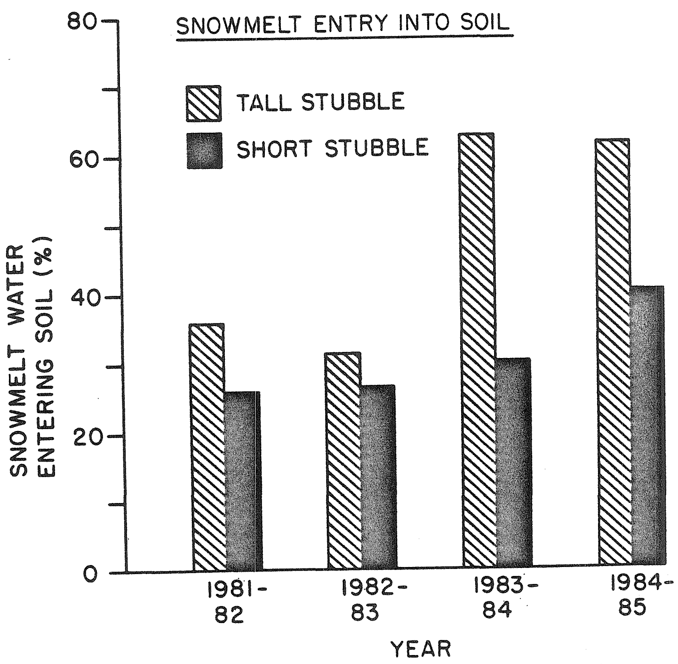

Fig. 4. Proportion of winter precipitation infiltrating into the soil

Thus, the trap strips not only are giving us the advantage of trapping more snow in winter, but by combining this technique with no-till cropping it may be providing extra advantages in soil water economy. In any event, the benefits of the trap strips in water conservation persist well into the growing season (Fig. 5).

Crop Yields - Effect of Fertilizer and Stubble Height

In the first two years of this study, growing season precipitation was fair to good (244 and 182 mm in 1982 and 1983, respectively) and yields were average to above-average. In these years, yields increased with rate of N fertilizer (Table 2). But, in the last two years there has been a severe drought (rainfall 100 and 73 mm, respectively, in 1984 and 1985) and crop yields did not respond to fertilizer application.

For each of the four years a significant yield increase caused by the use of trap strips in the test plots has been observed. This has been especially noticeable in the two dry years (Table 2).

Yields taken in the filler plot area, with its very low rate of fertilization, were lower than on test plots in the first two years when rainfall was adequate but, in the two dry years, filler plot yields were higher than test plot yields (Tables 2 and 3). To be realistic, since we live in an area where drought can be expected as a rule rather than the exception, farmers should seriously consider not over-fertilizing. Exceeding the soil test recommendation is perhaps not advisable. Note that in three of the four years of the test, the tall stubble treatment in filler plots outyielded the short stubble treatment significantly (Table 3).

When averaged over the years, there was no difference in yield due to N placement in spring (i.e., banded vs broadcast application of N) (Table 4). There was also no effect of time of application when the N was band applied. However, there was about a 100 kg/ha (1.5 bu/ac) lower yield when N was broadcast applied in the fall compared to the other fertilizer N treatments.

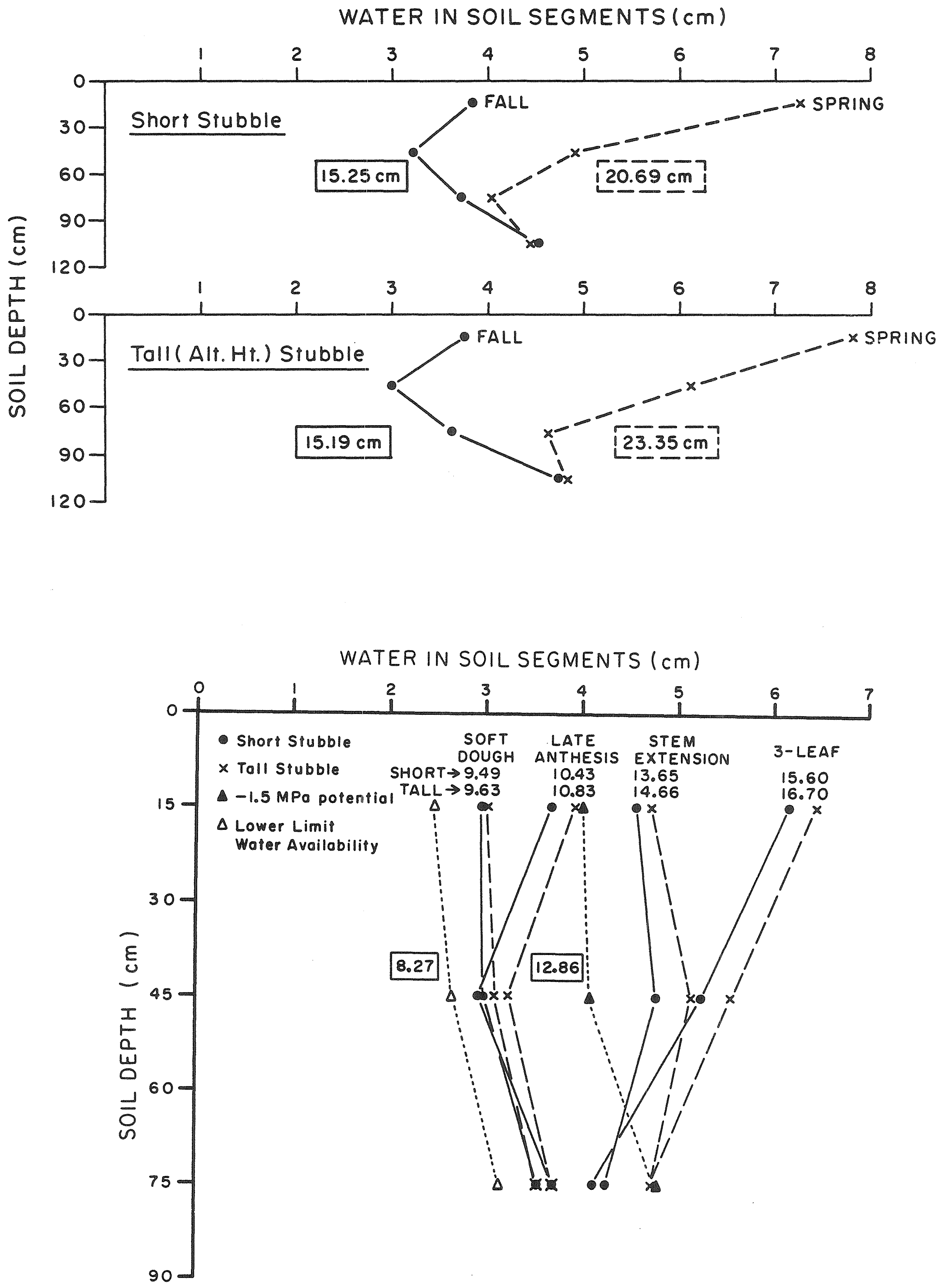

Fig. 5. Top: Overwinter soil moisture in short stubble trap strip plots (1984-85)
Bottom: Soil moisture use during the growing season

Table 2. ‡+Effect of stubble height and rate of N and P fertilizer on yield of spring wheat (1981-85)

Year	Stubble height	*Fertilizer applied (kg N/kg P_2O_5)	----------	----------	----------	Yield ($kg.ha^{-1}$)	----------	----------	----------	Mean Yield
1981-82		N/P_2O_5	25/120	50/120		100/120	150/120	100/60	100/30	
	Tall		2008	2226	-	2484	2416	2446	2375	2326
	Short		1813	2070	-	2662	2617	2627	2583	2395
	Mean		1911	2148	-	2573	2516	2537	2479	2361
1982-83		N/P_2O_5	25/120	50/120	75/120	100/120				
	Tall		1396	1635	1968	1988	-	1685	1864	1756
	Short		1358	1627	1651	1900	-	1608	1610	1626
	Mean		1377	1631	1809	1944	-	1647	1737	1691
1983-84	Tall		653	585	710	723	-	781	625	679
	Short		489	456	436	476	-	353	466	446
	Mean		571	521	573	600	-	567	545	563
1984-85		N/P_2O_5	25/60	50/60	75/60	100/60		100/45	100/30	
	Tall		784	683	546	645	-	618	603	646
	Short		554	514	523	462	-	509	464	504
	Mean		669	599	534	553	-	563	534	575
1981-85	Tall		1210	1282	1075	1460	(2416)	1383	1367	1352
	Short		1054	1167	870	1375	(2617)	1274	1281	1243
	Mean		1132	1225	972	1418	(2516)	1329	1324	1297

+ Values are meaned across method of placement and time of application.

‡ All main effects and several of second and third order interactions were highly significant.

* P rates were lowered in 1984-85. The 150 N rate was only used in 1981-82; it was changed to 75 N in future years.

(In well fertilized plots if tall stubble is rated 100, short stubble = 92).

Table 3. Effect of stubble height on spring wheat yields in filler plots (1981-85)

Year	Stubble height	‡Growing season precip. (mm)	Grain yield ($kg.ha^{-1}$)
1981-82	Tall		1418
	Short		1131
	Avg	244	1275
1982-83	Tall		1107
	Short		1181
	Avg	187	1144
1983-84	Tall		864
	Short		629
	Avg	100	747
1984-85	Tall		1000
	Short		749
	Avg	73	875
1981-85	Tall		1097
	Short		923
	Avg	151	1010
Statistical significance			Stub. *** Yr ***

+ N and P_2O_5 fertilizer applied with seed was each 25 $kg.ha^{-1}$ (1982-85) and 15 $kg.ha^{-1}$ (1981-82).

‡ May, June, July.

*** denote significance at $P < 0.001$.

During the two dry years there was no effect of either placement nor time of N application on yield (Table 4). In 1983, the year of average rainfall, all fertilizer N treatments except fall broadcast N gave similar yields; fall broadcast N gave 126-158 kg/ha (1.75 to 2.5 bu/ac) less yield than the other three treatments. In the wettest year (1982), fall broadcast N gave the lowest yield, spring banded N the highest yields and fall banded and spring broadcast N were equal. The yield difference between fall broadcast and spring banded treatments was 320 kg/ha (4.8 bu/ac) in 1982.

Table 4. [‡]Effect of method of N placement and time of application on yield of spring wheat (1981-85)

Year	Method of Application	[†]Time of Application		Mean
		Fall	Spring	
		- - - - - -	$kg.ha^{-1}$	- - - - - - -
1981-82	Banded	2373	2502	2438
	Broadcast	2177	2390	2284
	Mean	2275	2446	2361
1982-83	Banded	1733	1740	1736
	Broadcast	1582	1708	1645
	Mean	1658	1724	1691
1983-84	Banded	571	560	566
	Broadcast	566	553	560
	Mean	569	557	563
1984-85	Banded	576	572	574
	Broadcast	585	568	576
	Mean	580	570	575
1981-85	Banded	1313	1344	1328
	Broadcast	1227	1305	1266
	Mean	1270	1324	1297

[+] These values are averaged across stubble height and rates of fertilizer application.
[‡] All main effects and several of second and third order interactions were highly significant.
[†] In 1984-85 these treatments were early April vs. mid-May because early winter prevented a fall applicatio.

(If spring banded is rated 100, fall banded = 96.6; spring broadcast = 97.0 and fall broadcast = 91.3)

Economic Analysis

Data for the four years' results were analysed to compare net farm income associated with fertilizer treatments and stubble height. Net farm income was defined as the returns above all variable and overhead costs, except real estate taxes and investment costs for land. Particular emphasis was placed on the higher cost of N fertilizer and lower value of farm labor in the fall compared to spring, the higher cost for energy and labor associated with deep banding compared to broadcasting fertilizer, on the interest charges on operating capital, and for costs of weed control and harvesting. Prices used were those typical for a medium-sized farm with calculations based on 1984 prices (e.g., spring wheat was valued at $184/ton).

Some general conclusions from the economic analyses were as follows:

To date we have never lost money in the tall stubble treatment of the filler plots with their low fertilizer rates, even in the two dry years (Table 5).

Table 5. Effect of stubble height on spring wheat net return in filler plots+ (1981-85)

Year	Stubble height	‡Growing season precipitation (mm)	Net return ($.ha^{-1})
1981-82	Tall		130
	Short		80
	Avg	244	105
1982-83	Tall		53
	Short		66
	Avg	187	60
1983-84	Tall		6
	Short		-35
	Avg	100	-15
1984-85	Tall		-4
	Short		-48
	Avg	73	-26
1981-85	Tall		46
	Short		16
	Avg	151	31
Statistical significance			Stub. *** Yr ***

+ N and P_2O_5 fertilizer applied with seed was each 25 kg.ha^{-1} (1982-85) and 15 kg.ha^{-1} (1981-82).

‡ May, June, July.

*** denote significance at $P < 0.001$.

Table 6. +‡Effect of stubble height and rate of N and P fertilizer on net return for spring wheat (1981-85)

Year	Stubble height	*Fertilizer applied (kg N/kg P_2O_5)	Net returns $\$.ha^{-1}$							Mean net returns
1981-82		N/P_2O_5	25/120	50/120	75/120	100/120	150/120	100/60	100/30	
	Tall		96	118	--	169	78	162	164	131
	Short		60	87	--	198	113	187	200	141
	Mean		78	102	--	184	98	174	182	136
1982-83	Tall		-16	7	52	38	--	49	74	39
	Short		-23	10	38	20	--	11	31	8
	Mean		-19	8	24	29	--	30	52	24
1983-84	Tall		-147	-175	-173	-142	--	-135	-146	-153
	Short		-178	-200	-221	-177	--	-215	-174	-194
	Mean		-162	-188	-197	-160	--	-175	-159	-174
1984-85		N/P_2O_5	25/60	50/60	75/60	100/60	100/45	100/30		
	Tall		-118	-153	-195	-183	--	-196	-183	-171
	Short		-158	-183	-199	-208	--	-227	-208	-197
	Mean		-138	-168	-197	-196	--	-211	-196	-184
1981-85	Tall		-72	-81	-105	-55	--	-67	-23	-67
	Short		-100	-103	-141	-71	--	-93	-38	-91
	Mean		-86	-91	-123	-63	--	-80	-31	-79

+ Values are meaned across method of placement and time of application.

‡ All main effects and several of second and third order interactions were highly significant.

* P rates were lowered in 1984-85. The 150N rate was only used in 1981-82; it was changed to 75N in future years.

(In well fertilized plots if tall stubble is rated 100, short stubble = 92).

Wet Years

In the first two years when moisture was fair to good, money was made on all treatments; the most economical treatment was the one with 75-100 kg N/ha but low P (30 kg P_2O_5) (Table 6). This shows that we were fertilizing at too high a rate of P.

Spring application of N fertilizer provided higher economic returns than fall application and this was in spite of higher labor and fertilizer costs charged to the spring period (Table 7).

Table 7 +‡Effect of method of N placement and time of application on net returns for spring wheat (1981-85)

Year	Method of Application	*Time of Application Fall	Spring	Mean
		----------- $\$.ha^{-1}$		----------
1981-82	Banded	126	156	141
	Broadcast	111	146	129
	Mean	118	151	135
1982-83	Banded	23	27	25
	Broadcast	11	27	19
	Mean	17	27	22
1983-84	Banded	-176	-176	-176
	Broadcast	-165	-168	-166
	Mean	-171	-172	-171
1984-85	Banded	-183	-187	-185
	Broadcast	-169	-173	-171
	Mean	-176	-180	-178
1981-85	Banded	-53	-45	-49
	Broadcast	-53	-42	-48
	Mean	-53	-44	-49

+ These values are meaned across stubble height and rates of fertilizer application.

‡ All main effects and several of second and third order interactions were highly significant.

* In 1984-85 these treatments were early April vs. mid-May because early winter prevented a fall application.

(If spring banded is rated 100, fall banded = 97.6; spring broadcast = 97.0 and fall broadcast = 91.3).

Fall broadcasting N provided by far the lowest net returns of the four systems (Table 7).

Dry Years

In the two dry years, all fertilized test plot treatments resulted in loss of sizeable amounts of money with the loss being greater with increasing rate of fertilization (Table 6).

There was little difference in net farm income due to time of N application (Table 7).

Deep banding the fertilizer was less economical than broadcasting it when high rates of N were used (Table 7). This was because of greater cost for banding without affecting yield.

In all cases, the use of trap strips reduced the loss in net returns compared to stubble cut at conventional height (Table 6).

In 1985 we had to apply Roundup due to encroachment of grassy weeds and in all years we have had to use Hoegrass because the land has had a high infestation of wild oats. This has not helped the net return picture. Results would be better if goals were for economics rather than maximum yield.

CONCLUSIONS

The average extra gain in soil moisture from trap strips during the four years of study was 1.6 cm (0.6 inches) and in the two drought years the gain was 2.5 cm (1.0 inch). This made considerable difference in stubble crop survival.

There is evidence that zero-tillage may be increasing the rate of water infiltration into the soil. If so, this would solve one problem encountered with snow trapping, i.e., the high rates of runoff of snowmelt water.

There is no extra cost of leaving trap strips.

True, the zero-tillage will cost more due to herbicide costs; but to date, where we have applied conservative rates of fertilizer (25 kg/ha N and P_2O_5), we have actually made money in the first two (wet) years of the study and broke even in the drought years.

Therefore, farmers in southern Saskatchewan should be taking a close look at this system if they wish to find one that can be economically viable and yet environmentally acceptable.

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